# A Survey of Eight Major Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining

## INTRODUCTION

In the study area many small ephemeral, intermittent, and permanent streams are subject to burial as a result of mountaintop removal/valley fill (MTR/VF) activities. There has been little or no assessment as to what biota and habitats are being affected. Studies in other regions suggest that many intermittent and temporary streams may contain a diverse assemblage of species and aquatic biota. For example, in western Oregon taxa richness of invertebrates (> 125 species) in temporary streams exceeded that of 100 species found in a permanent headwater (Dieterich and Anderson 2000). In several northern Alabama streams, Feminella (1996) could find little difference between the number of invertebrate taxa found in permanent streams versus those found in intermittent stream reaches. In contrast, some studies have found taxonomic diversity to be depressed in intermittent headwater streams compared to permanent downstream reaches (Brussock and Brown 1991).

Dieterich and Anderson (2000) found 13 previously undescribed taxa of invertebrates associated with the temporary headwater stream. Morse et al. (1993, 1997) have pointed out that many small spring brooks and spring seeps in the Appalachian region harbor a diverse and unique array of invertebrates. Furthermore, a number of the unique species are known from only one or two isolated locations in the Appalachians (Morse et al. 1993, 1997). However, other than the knowledge that small spring brooks and spring seeps may contain unique species in the Appalachians, we know little about benthic community structure and distribution in intermittent streams within the coalfield area. In order to assess community structure in these small headwater streams potentially subject to burial, a survey was undertaken during the late winter and early spring of 2000 to assess biotic inventories in several intermittent and permanent headwater stream systems.

The purpose of the survey was to assess the potential limits of viable aquatic communities based on biological criteria, which may be useful in delineating stream buffer zones as they relate to valley fills created by MTR/VF practices. Specifically, several questions were addressed by the exercise: What are the upper limits of distribution of aquatic insects belonging to the orders Ephemeroptera, Odonata, Plecoptera, Megaloptera, Trichoptera, Coleoptera, and Diptera within the intermittent and permanent headwater reaches? What is the distribution of various functional groups of aquatic insects, i.e., shredders, collectors, gatherers, and predators in these headwater streams? How does invertebrate community structure and taxa diversity vary with distance from the headwaters and watershed area? What is the relative distribution of taxa with regard to length of aquatic life required to complete development, i.e., are only those taxa with shorter (<9 months) life cycles found in the intermittent headwater reaches? To assess these questions streams were studied in southern West Virginia and eastern Kentucky, where all or parts of the streams are scheduled for burial by MTR/VF mining. It should be emphasized that most of the streams included in this inventory do not appear on USGS 1:24000 maps and, in fact, many do not even appear as a dashed blue line indicating the existence of an intermittent stream on existing USGS maps.

## METHODS

### Field methods

Five proposed surface mining sites in West Virginia and one site in Kentucky were selected for study. Each site had three or more headwater streams planned for valley fills. A total of 36 streams and spring seeps were sampled in West Virginia and Kentucky. Three of the 36 are reference streams. All streams and spring seeps were sampled between February 15 and April 15, 2000.

Two field teams, four to five members, were organized to conduct the stream surveys. Each team had a professional biologist with experience in aquatic macroinvertebrate taxonomy, and one person with experience using global positioning systems (GPS).

The first sampling point for each headwater stream was located in the field, where the contiguous surface flow began. Other sampling locations were located 50, 150, 350, and 550 meters downstream of the point of contiguous flow using a 100-meter tape. If needed, additional points were sampled at 400-meter intervals downstream until the mouth of the stream was reached, or a perennial stream as designated by a solid blue line on a USGS topographic map was encountered. Each sampling point was located on a USGS 7.5' topographic map and the GPS location recorded. Location information was recorded into a geographic information system and used to calculate watershed area, elevation and aspect at each sampling point. Again, many of these headwater streams are not shown as either intermittent or perennial streams on USGS 1:24000 maps.

At each sampling location, only aquatic insects in the orders Plecoptera, Ephemeroptera, Odonata, Megaloptera, Lepidoptera, Trichoptera, Coleoptera and Diptera were collected. Aquatic stages were taken with a D-frame net and hand picked with forceps from rocks and leaf-packs by three or four team members for ten minutes. The specimens were counted and identified to the family or genus level, and then preserved in ethyl alcohol for laboratory verification of counts and field identifications.

### Data collected

The following information was gathered for each sampling point: site ID and station number; downstream distance from point of contiguous flow; area of watershed, elevation, stream aspect (compass orientation), number of individuals collected for each taxa, total number of taxa collected (richness), number of multi-year taxa (taxa which require >1 year for development in the aquatic juvenile stage), number of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa, proportion of collectors, shredders, scrapers, and predators in the population. Multi-year life cycle data were obtained from Brigham et al. (1982) and Wallace and Anderson (1996). Functional group classification followed that presented in Merritt and Cummins (1996). For the proportion of functional groups at a given station, any station with $\leq 2$ individuals was eliminated prior to analysis because they did not constitute a community.

## RESULTS

Total individuals, orders, families, and genera

All 8 of the target orders of insects were found within the intermittent headwater reaches and within these orders there were 41 families and 73+ genera, the actual number of genera would far surpass 73 as chironomids were not identified to genus (Table 1). A total of 6,923 individuals were collected and identified from the study streams. Functionally, predators (24 taxa) dominated the total number of taxa collected followed by collectors (19 taxa), shredders (18 taxa), scrapers (5 taxa), and several facultative collector-scraper taxa based on the classification scheme of Merritt and Cummins (1996). Many of the genera listed in Table 1 are represented by more than one species in the study area. For example, a list of Plecoptera (stonefly) genera found in small headwater streams and spring seeps in eastern North America (Table 2) shows that over half of those genera listed are represented by multiple species. Additionally, the study area has not been adequately inventoried and a few species are known from only a few isolated localities.

Taxa richness and EPT richness

Taxa richness (number of taxa at a given site) increased ($P$<0.01, regression analyses) with increasing watershed area (Figure 1). The number of taxa increased rapidly up to a drainage area of about 150 to 200 acres and then tapered off with increasing watershed area. Many watersheds of less than 50 acres had 10 or more taxa.

The total number of EPT taxa (number of taxa belonging to the insect orders Ephemeroptera, Plecoptera, and Trichoptera and generally considered obligate aquatic insects indicative of good water quality) followed similar trends as taxa richness (Figure 2). In fact, the number of EPT taxa increased rapidly up to a watershed area of about 100 acres after which the rate of increase tapered off with increasing watershed area (Figure 2, $P$<0.01, regression analyses). As noted for taxa richness some extremely small spring seeps at the point of contiguous flow had multiple EPT taxa (Figure 2).

Functional differences in fauna along headwater gradients

The proportion of shredder taxa declined with increasing watershed area ($P$<0.01, regression analyses, Figure 3). In many of the smaller headwater drainages of less than 50 acres over half of the fauna collected were shredders. Collector taxa showed an opposite trend than that of shredder taxa. The proportion of collector taxa increased with increasing watershed area ($P$<0.01, regression analyses), with the rate of increase slowing once a watershed area of about 100 acres is reached (Figure 4). The proportion of samples composed of scraper taxa followed a similar, although weaker but significant ($P$<0.05), trend as that of collectors with increasing proportions as watershed area increased (Figure 5). In contrast to the other functional groups, the percent predators showed no trend with increasing watershed area or distance downstream ($r^2 = 0.0085$, Figure 6).

**Table 1**. Insect order, number of families and genera within each order found during survey of streams potentially subject to valley fills within the study areas.

| Order | Number of families | Number of Genera |
|---|---|---|
| Ephemeroptera (mayflies) | 4 | 8 |
| Odonata (dragonflies & damselflies) | 3 | 4 |
| Plecoptera (stoneflies) | 9 | 21 |
| Megaloptera (alderflies, dobsonflies) | 2 | 3 |
| Coleoptera (beetles) | 5 | 5 |
| Trichoptera (caddisflies) | 8 | 12 |
| Lepidoptera (moths) | 1 | 1 |
| Diptera (true flies) | 9 | 19[a] |
| Total = | 41 | 73+ |

[a] = does not include Chironomidae genera

**Table 2.** Plecoptera (stoneflies) from eastern North America found only in first and second order streams, including seeps and springs (list compiled by R. F. Kirchner [U.S. Army Corps of Engr.] and B. C. Kondratieff [Colorado State University]). Note – ca. 50% of these species have been described as new to science in the last 25-30 years.

| **Family** | **Genus** | **Number of known species** |
|---|---|---|
| CAPNIIDAE | *Allocapnia* | 5 |
| | *Paracapnia* | 1 |
| LEUCTRIDAE | *Leuctra* | 6 |
| | *Paraleuctra* | 1 |
| | *Megaleuctra* | 2 |
| NEMOURIDAE | *Nemoura* | 1 |
| | *Ostrocerca* | 4 |
| | *Paranemoura* | 2 |
| | *Prostoia* | 1 |
| | *Soyedina* | 5 |
| | *Zapada* | 2 |
| TAENIOPTERYGIDAE | *Taeniopteryx* | 1 |
| CHLOROPERLIDAE | *Alloperla* | 2 |
| | *Rasvena* | 1 |
| | *Sweltsa* | 4 |
| PELTOPERLIDAE | *Peltoperla* | 2 |
| | *Tallaperla* | 5 |
| | *Viehoperla* | 1 |
| PERLIDAE | *Beloneuria* | 2 |
| | *Hansonoperla* | 2 |
| PERLODIDAE | *Isoperla* | 4 |
| | *Malirekus* | 2 |
| | *Oconoperla* | 1 |
| | *Yugus* | 3 |

Total number of individuals collected and life history

The total number of individuals collected at various sites increased with watershed areas ($P<0.01$, regression analyses, Figure 7). Overall the number of taxa collected increased rapidly from watershed areas of <10 to 100 acres and the rate of increase began to slow after watershed drainage areas approached 100 acres. The number of taxa with multi-year life cycles, i.e., requiring more than one year in the aquatic stage to complete their development, tended to increase in a downstream direction (Figure 8). Insects with multi-year life cycles were encountered in watersheds as small as 10 acres. However, even 100-acre watersheds had as many as 4 taxa with multi-year life cycles. Some of the multi-year taxa include the following: Plecoptera (stoneflies): *Peltoperla, Tallaperla, Eccoptura,* and *Acroneuria;* Odonata (dragonflies): *Lanthus*, *Cordulegaster*, and *Stylogomphus*; Megaloptera (fishflies): *Nigronia*. Coleoptera (beetles): *Anchytarsus.*

## CONCLUSIONS

Most of these sites would not be considered streams based on existing USGS 1:24000 topographic maps. Furthermore, a number of taxa that are found in these extreme headwaters have multi-year life cycles suggesting that sufficient water is present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. The predominance of shredder taxa in the headwaters (Figure 3) suggests that the community structure in the extreme headwaters resemble those hypothesized by the river continuum concept for first order streams (Vannote et al. 1980). These streams all drained forested regions and leaf material from the surrounding forest was by far the most evident energy source (e.g. Wallace et al., 1997) as many streams were “choked” with leaves during the February to April sampling period. Much more work is needed on organic matter dynamics, e.g., input and output budgets, etc. in these small headwater streams of the central Appalachians. Furthermore, trend of increasing fine organic particle collectors downstream (Figure 4) suggests a system that is dependent on linkages upstream resources and surrounding forest. It is assumed that export to downstream areas is linked to both hydrologic events and animal activity (e.g. shredders processing leaf material to FPOM, which is more easily exported to downstream reaches).

Although only contiguous flow areas were considered in this study, the sampling was conducted following groundwater recharge from a major drought the preceding year. Presumably, these extreme headwaters are subject to annual surface drying. Benthic invertebrates exploiting temporary stream habitats have been separated into three groups of taxa: 1) those found primarily in permanent waters and displaying no specialized adaptations to life in intermittent waters; 2) generalist taxa that are facultative stream/pond generalist; and, 3) specialist species with specialized life cycles or adaptations for withstanding adverse periods of drying (Williams and Hynes 1977). For example, some invertebrates survive drought periods by migrating into the subsurface sediments known as the hyporheic zone (e.g., Clinton et al. 1996), whereas others may survive drought periods in intermittent pools, etc. (e.g. Smith and Pearson 1987), or have drought resistant stages or adaptations (Williams and Hynes 1977). However, to our knowledge none of the taxa identified above as having multi-year life cycles have any obvious specialized adaptations for surviving droughts, which suggests migration into hyporheic zones or intermittent pools during severe droughts. A number of workers have found remarkable similarity between fauna in temporary stream habitats with that found in nearby permanent streams (Feminella 1996, Delucchi 1989, Boulton and Lake 1992), whereas other have noted rather distinct differences among permanent and temporary forest streams (Dieterich and Anderson 2000).

Biodiversity

There are many species of aquatic vertebrates and invertebrates that are unique to headwater streams and spring seeps (Morse et al. 1993, 1997). For example, several species of aquatic insects that have been described (new to science) from first and second order streams in recent years from Kentucky, Virginia and West Virginia, include: *Hansonoperla hokolesqua, Allocapnia frumi, A. harperi, Alloperla aracoma, Peltoperla tarteri, Sweltsa pocahontas, Ameletus tarteri* and *Madeophylax* A list of Plecoptera (stoneflies) and number of species restricted to first and second order streams of eastern North America is presented in Table 2. It is important to emphasize that about 50% of the number of stonefly species listed in Table 2 have been described only within the last 25 to 30 years and new species are still being described from the region. Some of the taxa collected during this study restricted to small headwater streams, for instance: *Ostrocerca*, *Soyedina,* and *Peltoperla* (Plecoptera), *Diplectrona metaqui* Ross (a new WV state record), and *Homoplectra* (Trichoptera). For example, the larvae of *Homoplectra* now known occur in intermittent spring seeps in the headwaters of mountain stream (Huryn 1989). Thus, the view that there are so many small streams and springbrooks in the Appalachians that destroying a small portion represents a minor threat to biodiversity appears to be incorrect.

Very few taxonomic studies to the species level of identification (generally requiring the short-lived aerial adult stage) have been made in the small intermittent and permanent streams of the central Appalachians (see also Morse et al. 1993, 1997). This includes streams of the Kentucky, Tennessee, Virginia, and West Virginia coalfields. Thus, without adequate assessment by trained taxonomists, we do know how many species are present, their distribution, their current population status, or whether they are endangered or threatened with extinction. Hence, we are burying some potentially valuable and unique habitats without knowing the consequences of our actions. Investigations into the taxonomy, ecology, and distribution of species associated with headwater streams and spring seeps in MTR/VF areas should proceed with haste in order to document biotic inventories of the coalfield areas before many species are potentially lost forever without realizing their presence.

As others have pointed out, invertebrates inhabiting temporary streams can have high diversity and faunal similarity with permanent streams, therefore they should be considered in conservation plans designed to protect species and their habitats (Williams 1996, Feminella 1996).

## ACKNOWLEDGEMENTS

The field teams for this investigation included Ross Bishop (DSMRE), Natalie Carter (OSM), Bob Fala (WVDEP), Gary Hall (OSM), Fred Kirchner (USCE), Thomas Koppe (OSM), Max Luehrs (OSM), Jason Miller (USFWS), Kevin Quick (WVDEP), Dave Rider (USEPA), Ted Sentz (OSM), W. M. Rowe (DSMRE), Dr. Ben Stout (WJU), Richard Wahrer (DSMRE), Vann Weaver (OSM), and Susan Wind (DSMRE). The draft report was assembled in haste by Fred Kirchner, Ben Stout, and Bruce Wallace.

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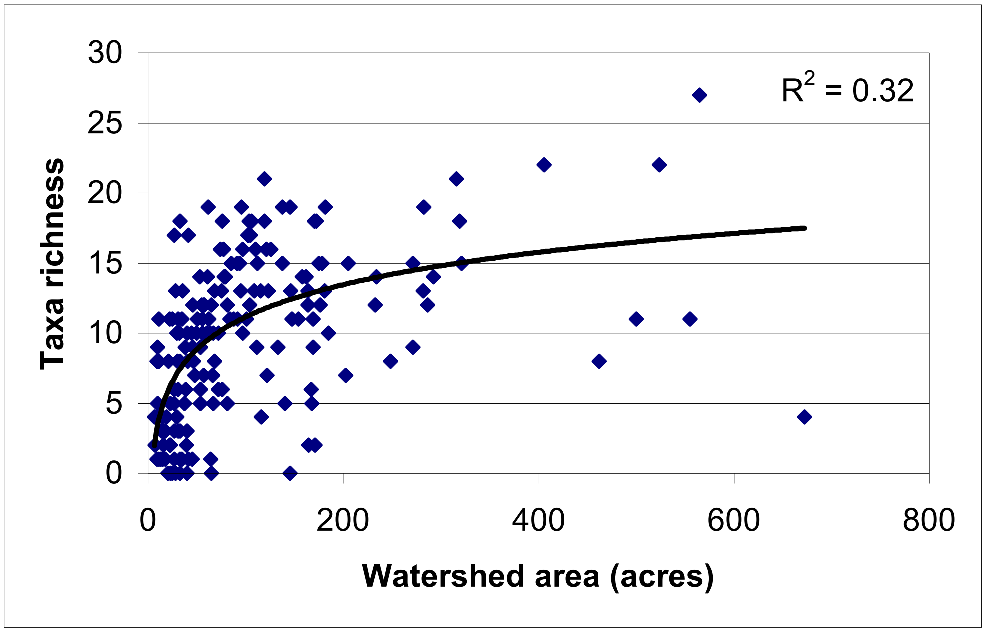


Figure 1. Number of different benthic macroinvertebrate taxa (richness) collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

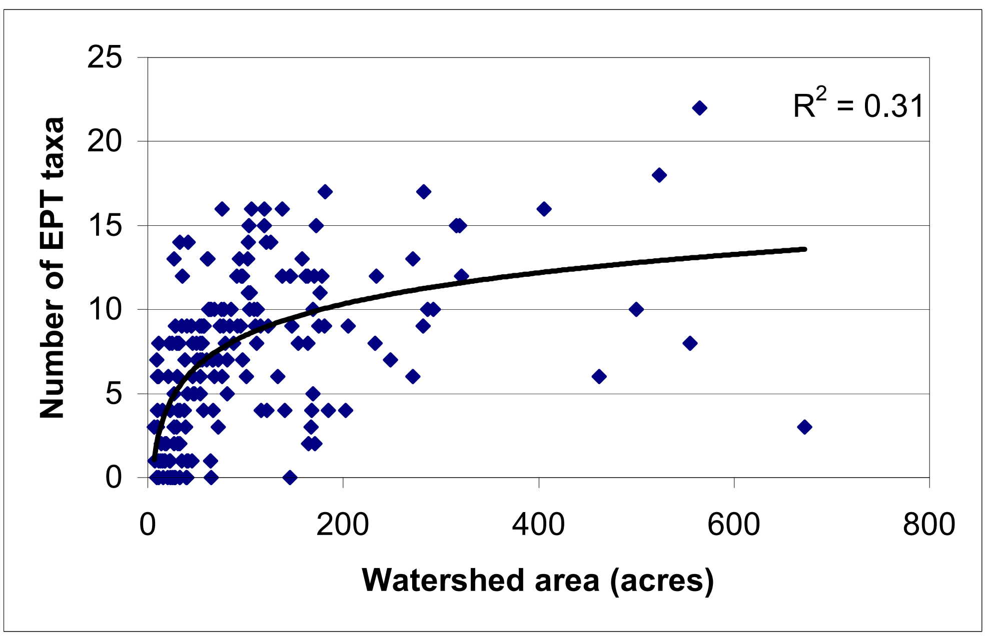


Figure 2. Number of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

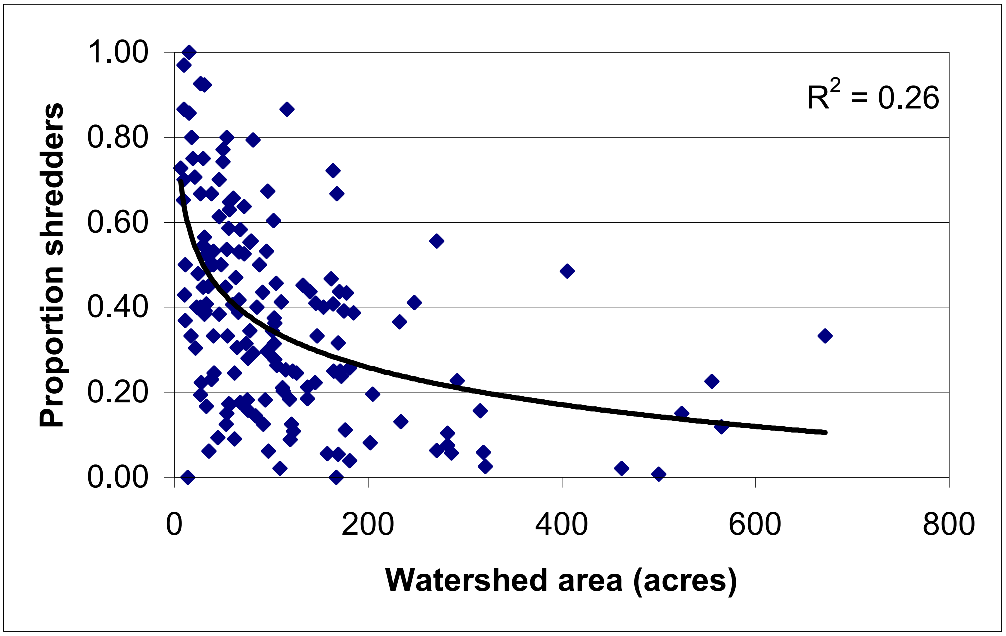


Figure 3. Proportion of benthic macroinvertebrate populations that function as leaf shredders collected in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

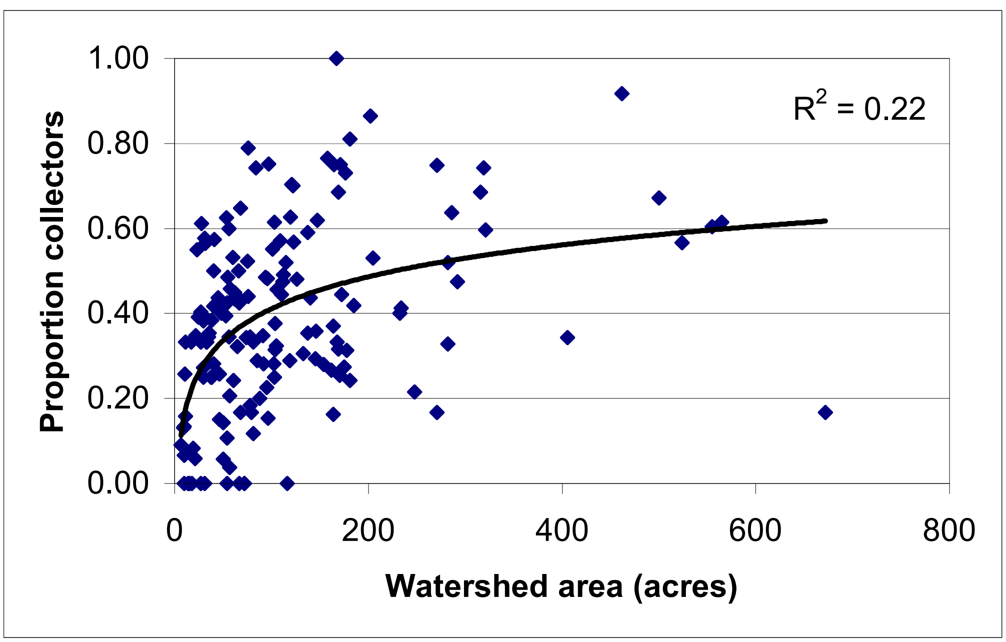


Figure 4. Proportion of benthic macroinvertebrate populations that function as fine particle collectors in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

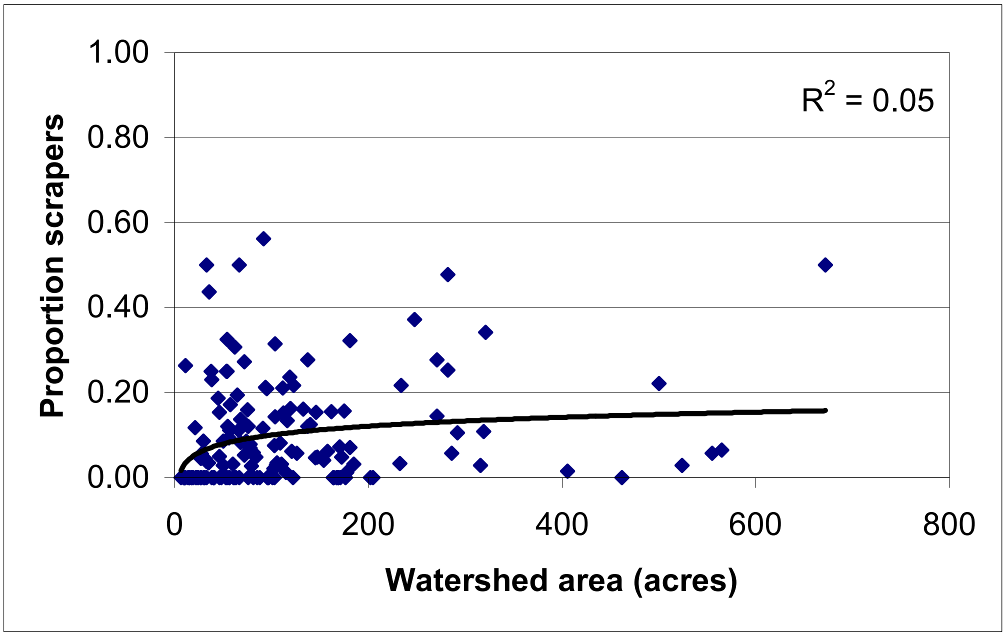


Figure 5. Proportion of benthic macroinvertebrate populations that function as biofilm (algae, bacteria, fungus) scrapers in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function.

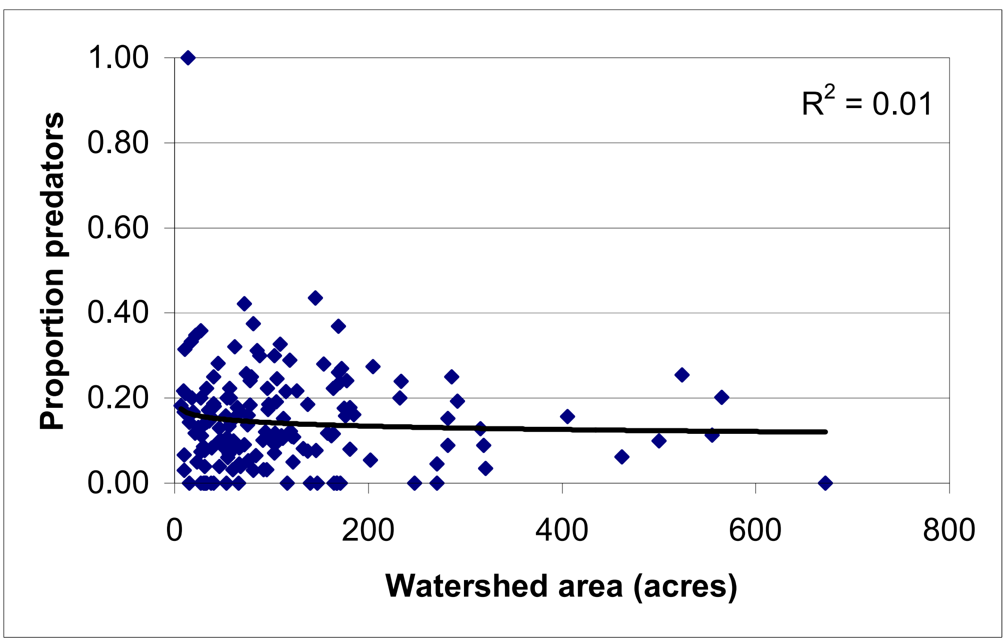


Figure 6. Proportion of benthic macroinvertebrate populations that function as predators in each sample, versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is not significantly different than zero ($p>0.01$).

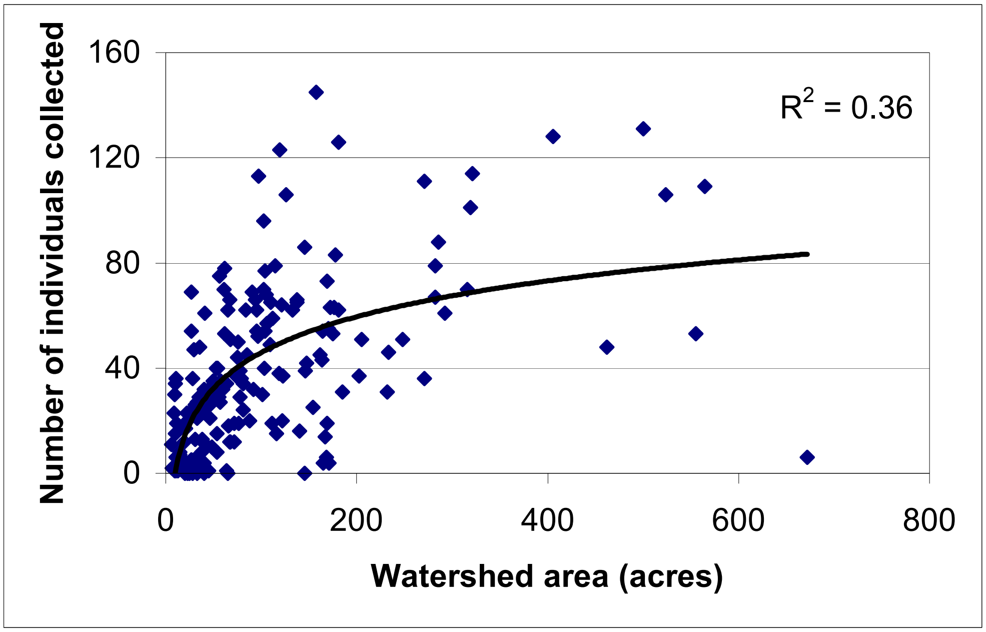


Figure 7. Total number of benthic macroinvertebrates collected in each sample versus watershed drainage area at each sample location. Trendline fitted using the least squares method and a logarithmic function. The relationship is significantly different than zero ($p<0.01$).

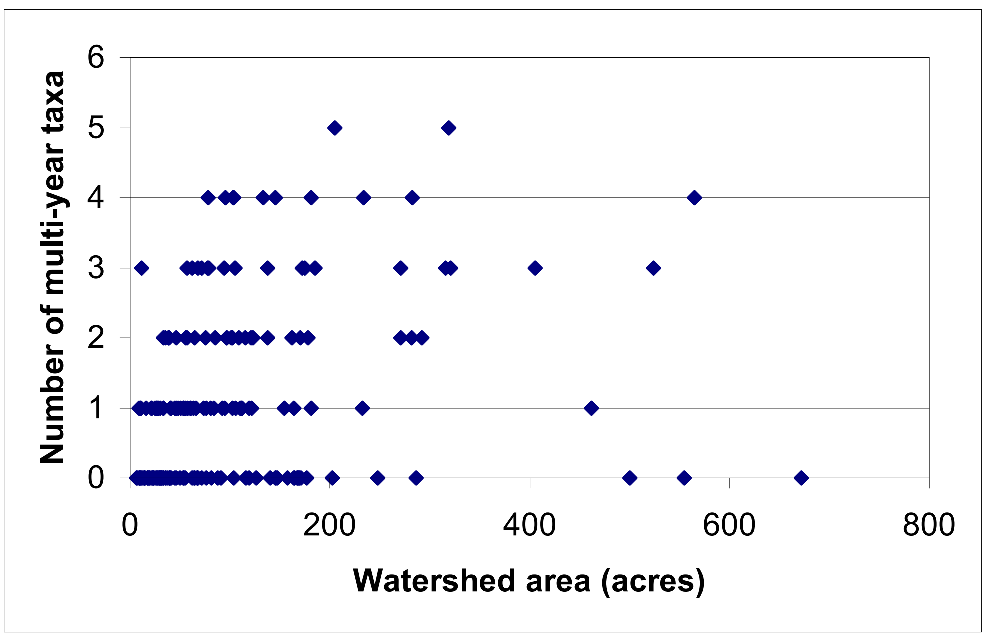


Figure 8. Number of taxa collected in each sample that live greater than one year in the aquatic life stages, versus watershed drainage area at each sample location.